AD-A156 730   THE ROLE OF AUTOMATED WAR GAMING IN STRATEGIC ANALYSIS   1/1
              (U) RAND CORP SANTA MONICA CA   B W BENNETT ET AL.
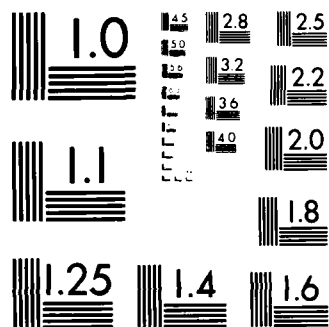   DEC 84 RAND/P-7053

UNCLASSIFIED   F/G 15/7   NL

END
FILMED
DTIC

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

THE ROLE OF AUTOMATED WAR GAMING
IN STRATEGIC ANALYSIS

Bruce W. Bennett and Paul K. Davis

December 1984

P-7053

I. INTRODUCTION

For the last several years, The Rand Corporation's Strategy Assessment Center (RSAC) has been developing a new framework for strategy analysis. This paper reviews the effort and discusses early RSAC experience with *automated war gaming*, which includes not only computerized force modeling and bookkeeping, but also automated decision making. Thus, we allow for either partial automation in which a human team plays with automated support (e.g., optional detailed planning packages), or full automation in which the computer makes all of the decisions and literally runs the war game without human intervention-- using decision models with variable rules. Although the latter mode facilitates rapid simulation, it creates new and interesting requirements and opportunities for human analysts. We shall discuss some of them in what follows.

BACKGROUND

In the mid- to late-1970s, many DoD studies strove to evaluate the balance of strategic forces between the United States and the Soviet Union. As the studies progressed, the inadequacy of the analytic tools available for addressing this kind of question became clear. After considerable thought, the DoD sought a fundamentally new approach, combining war gaming and analytic modeling. The belief was that a war gaming framework would help overcome the otherwise sterile scenarios used in strategic force analysis, while coupling such an approach with analytic models would lend a degree of rigor. Rand was charged with the research after proposing an approach that would gain control over the variables by automating the entire war game (Graubard and Builder, 1980); for a more detailed description of the RSAC background, see Davis and Winnefeld, 1983.

From the outset, Rand has emphasized a flexible approach providing options for human, automated, and mixed war gaming. The war gaming approach has indeed produced a rich environment for analysis, around which we have built a tool to allow the user to "sand table" most forms

of major warfare. Although the initial focus was on strategic forces, it became obvious that we also had to handle major conventional conflicts as well, since the use of strategic forces seemed most likely to escalate from theater conflict. Furthermore, most analysts felt that the outcomes of theater conflicts were critical to the outcome of the war even after the employment of strategic forces. We are therefore producing a simulation of integrated, global conflict, which assesses the capabilities of both conventional and nuclear forces in various contingencies. We have also emphasized model flexibility that facilitates sensitivity testing of both military and political issues-- providing the capability to answer a broad range of "what if?" questions quickly.

CURRENT STATUS

We have now completed two years of intensive development and are experimenting with and improving an operational prototype system. This paper is based upon our experience as of January 1985. As work progresses, some conclusions may change--i.e., this paper should be treated as a "work-in-progress" document.

Accession For

NTIS GRA&I

A-1

II. THE RSAC APPROACH TO WAR GAMING

THE EVOLUTION FROM TRADITIONAL WAR GAMING

Most traditional war gaming involves a competition between two human teams (generally designated Red and Blue), as moderated by a human control team. The RSAC system allows the Red and Blue teams to be represented by models called Red and Blue "Agents" (see Fig. 1). The Red Agent plays the role of a Soviet dominated alliance, and the Blue Agent assumes the role of a U.S. led alliance. We can also represent the control team functions with: (1) a "Scenario Agent" that models the actions of all other countries, (2) a "Force Agent" that keeps track of military forces worldwide and the consequences of combat, and (3) a "Systems Monitor" that controls the interactions of the Agents and provides the record keeping functions of the system.
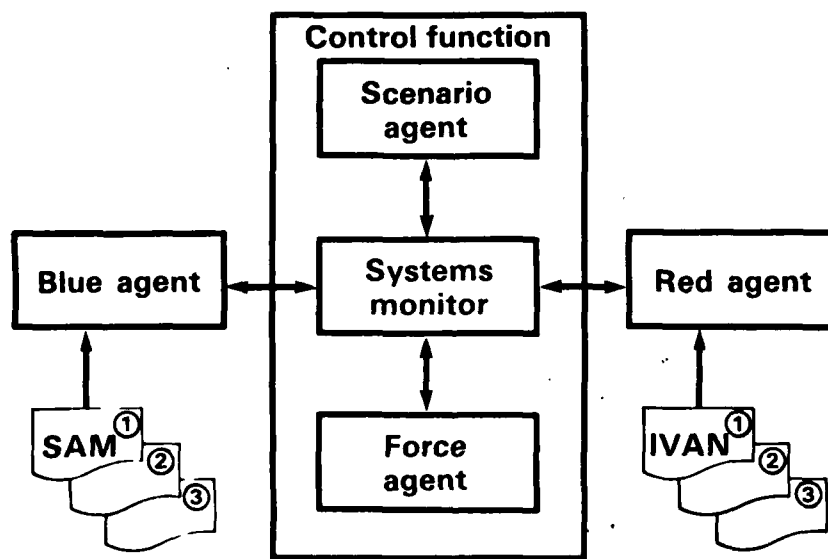
Fig. 1 -- The automated gaming structure

The Scenario Agent representations are not as detailed as those of the Blue and Red Agents, focusing instead on such political decisions as a nonsuperpower turning its forces over to Major Agent (Red or Blue) control or granting overflight or basing rights. Thus, we refer to the RSAC's approach as a "2+ sided game," where most conflict occurs between Red and its allies and Blue and its allies (though other countries are capable of some independent actions). When using the automated agents, we can select alternative behavior patterns or "personalities" (alternative "Ivans" and "Sams").

The automated Major Agents have a hierarchical four-level structure (see Fig. 2 and Davis, 1984). The National Command Level (NCL) performs the functions that would be expected of the national political leadership. The General Command Level (GCL) performs the actions of the central military staff and diplomatic staffs--for example, the actions of the Joint Chiefs of Staff, plus some actions by the State and NSC staffs. Below the GCL is the Supertheater Command Level (SCL) and the subsidiary Area Command Levels (ACLs), which represent specific theaters of conflict.
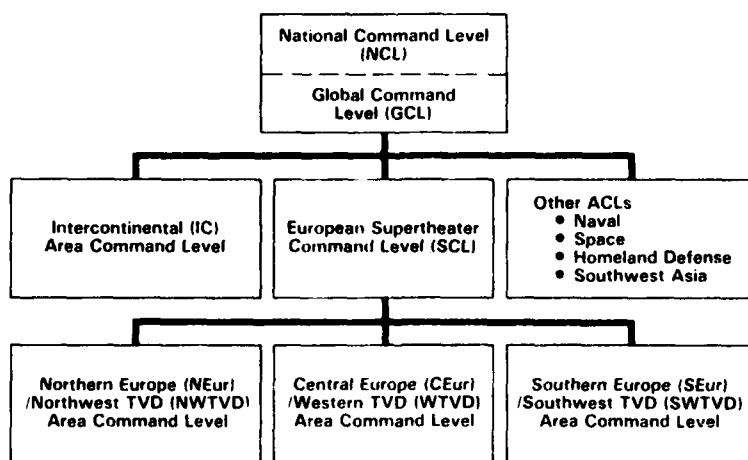

Fig. 2 -- Model hierarchy within the Red and Blue Agents

The automated NCL can be described as a process model, whereas the other levels of the Major Agents are modeled by "scripts," which represent analytic versions of war plans *plus* the adaptations made by military commands as conflict proceeds. The NCL assesses the current situation in various theaters and makes fundamental choices about escalation control, national objectives, and the basic strategies to implement in each theater. The strategies chosen by the NCL are called analytic war plans; they reflect a systematic concept of how to conduct military operations, including specific guidelines (called "wake-up rules") on when the plan should be reviewed or reconsidered. Once implemented, a particular analytic war plan designates the script of actions for each of the lower levels in the Major Agent hierarchy. In most cases, these scripts are relatively robust, including procedures for adapting to circumstances consistent with the authority that has been specifically delegated to each command. When a wake-up rule is triggered by a problem that the plan or script is not prepared to deal with, a lower level in the structure will seek direction from the higher levels, expecting that more resources will be committed, further authority will be delegated, or that the existing plan will be changed.

To make the logic of rule-based Agents (Red, Blue and Scenario) more readable, Rand has developed a new computer language called Abel. A few notional examples will show what we mean by this. For example, in the NCL, we might see a Red rule something like, "If NATO_seeking_nuclear_release is yes, then implement plan preempt_against_NATO." In this case, "NATO_seeking_nuclear_release" refers to a subroutine that details what would constitute intelligence indicators that NATO was preparing for a nuclear strike. The plan implemented would potentially involve various components at each of the other levels of the hierarchy. At the ACL, there might be a Red rule like, "If breakthrough_test is yes, then let the plan_outcome be the report from exploit_breakthrough." At this lower level, both "breakthrough_test" and "exploit_breakthrough" are subroutines that contain the detailed information necessary to test a situation and implement a series of actions, respectively. Abel also allows decision tables to be implemented as source code, thereby enormously simplifying the clarity of rule-based programs.

OTHER DECISION ELEMENTS

We have also provided two lower levels of control called the Operational and Tactical Control Levels (OCL and TCL). For example, the theater-level ground-combat OCL (which we refer to informally as "the CINC") allows a defender (team or ACL plan) to set priorities among sectors for resource allocation and other policy variables. The OCL then allocates reserves and supplies to each sector, shifts boundaries, and redeploys forces. The OCL models are essentially expert systems, embodying rules developed after repetitive human play by experienced military officers and analysts. Having such OCL models is important not only to closed simulations, but also to human play because human teams seldom want to spell out daily force orders--they want to specify philosophy.

The TCL is an abstraction consisting of decision rules distributed throughout the Force Agent. Parameters that control the rules are set by the automated or human players. For example, a TCL rule might prevent a would-be attacker from starting an attack in a given corps sector until he has at least a 2-to-1 force ratio advantage in that sector. While this rule is still in the Force Agent, the 2:1 ratio may be changed by the ACL to be 1.5:1 or 3:1 or any other reasonable alternative.

PLAYING A WAR GAME

The actual play of the game begins with the Systems Monitor in control, polling the Red, Blue, and Scenario Agents to determine whether or not they desire to take any actions. Once all have completed the desired moves, the Force Agent begins to simulate the military consequences of the actions taken, and proceeds until one of the Agent wake-up rules is triggered. Note that the RSAC differs significantly from most war games in that the game is not run in "real time" where, for example, one hour of playing time might represent six hours of elapsed time in the simulated war. The real-time playing mode penalizes decisionmakers if they do not make decisions quickly enough; we did not believe that such an approach was appropriate when automating the players.

The automated Major Agents can interact directly with the Force Agent and its models in three basic ways: (1) they can request information about the current state of the world (some examples will be shown below), (2) they can send orders instructing forces to take specific actions, and (3) they can set parameters in the TCL. They can also acquire information on future events as part of the "look-ahead" process (as described below), and can pass wake-up rules indirectly to the Force Agent through the Systems Monitor.

The orders that can be sent are illustrated by two possible examples:

    Alert   H_bombers   US-NE   US   CEur   60%
    Execute   US   Intercon   Main_plan   Counterforce

where the first requests that the alert rate be increased to 60 percent for heavy bombers in the Northeastern United States assigned to the Central European theater, and the second orders the execution of all intercontinental forces assigned to the counterforce option of the main strategic targeting plan. In preparing plans for the automated Major Agents, a table structure is used for these orders to indicate the role of each of the parameters specified. For human use, the computer prompts the user for each desired parameter.

An example of parameter setting for a human player is:

    Set   WTVD   Mass_width   10

In this case, the Red team is indicating that forces pursuing massed attacks in the Western TVD (TVD is the Soviet abbreviation for theater of conflict) should do so along 10 km fronts. The term "mass_width" is certainly not as informative as one might wish, and this aspect of the interface is scheduled for improvement in the near future.

HANDLING BRANCH POINTS

Several other important aspects of the RSAC gaming structure relate to how we handle the problem of a "branch" or decision point. For example, if the Red Agent is succeeding in a conventional attack in Europe, but Blue actions trigger its wake-up rule relative to NATO nuclear attack preparations, Red is faced with a decision on how to proceed. It may initially choose a nuclear preemption plan as a response, but before actually implementing that plan, it would like to determine what the potential outcomes of it might be. We do this in the RSAC system by using what we call a look-ahead. In a look-ahead, the game is temporarily halted, and the current state of the world saved. In this case, the Red Agent would then test its plan against its perceptions of how Blue would likely respond (where the Blue responses must be played at the same level of detail as the basic Blue Agent). If the Red plan achieves the desired objectives, then the look-ahead is terminated, the game returns to the saved point, and Red proceeds to implement its plan. If the Red plan fails to achieve the desired outcomes, then Red returns to the saved state and attempts to run an alternative plan in the look-ahead mode, until a successful plan is found. In this process, Red may even have to consider changing objectives or altering escalation guidance in order to finally arrive at a plan with an agreeable outcome.

Note that this same approach has tremendous value in an analytic study. Assume that a single analyst is playing all of the Agent roles and has reached the point where the reaction by either side or both is uncertain. He can save the current state, evaluate one potential set of actions, return to the saved state, and evaluate a separate course of actions, and so forth.

III. MODELING GLOBAL CONFLICT

Having described the full RSAC system briefly, let us now discuss
the Force Agent in somewhat more detail. Thought on the Force Agent's
design began in 1982 (see Davis and Williams, 1982; and Bennett,
unpublished). As suggested earlier, we realized that we would have to
handle all forms of conflict from major combat in a particular theater
through strategic nuclear warfare, and do so in an integrated manner.
The resulting model would have to be flexible, transparent, interactive,
and fast, especially in support of the look-ahead concept. Indeed, the
Force Agent should provide a "sand table" for strategic force analysis.
We were also concerned that many existing models neglect military
operations that are difficult to model and yet may determine conflict
outcomes (e.g., mobile SAMs); at the very least, we felt we should
capture the effects of these operations (e.g., higher attrition to
penetrators).

Naturally, we would have preferred to start with an existing model
to limit our efforts. However, a rather extensive search failed to
produce any good options of this sort. Early in the process, Rand
developed a primarily strategic forces model (FOMENT) as part of the
RSAC. When our focus became more general, we began to look for other
alternatives. One approach of interest was the Strategy and Force
Evaluation (SAFE) games carried out at Rand in the early 1960s (see for
example Brown and Paxson, 1975). The second phase of the SAFE games
involved a global (mainly strategic forces) conflict carried out without
computer assistance. What impressed us about this framework was that
even after 20 years many of those who had played in the SAFE games could
remember the character of their war plans, what went well and what went
poorly, and why problems developed. It seemed clear that this structure
and level of aggregation had much to offer.

THEATER OPERATIONS

The RSAC approach evolved rather quickly once development began. Most forces are identified by country, though we divide larger countries like the United States and the Soviet Union into several regions. We also add a more detailed geographic overlay in several likely theaters of combat. Forces are moved into the overlays either over land (such as forces moving from the Soviet Union into the Western TVD), or by strategic airlift or sealift (e.g., moving forces from the United States into Central Europe). Even with this approach, we are completely integrated: for example, if a nuclear attack strikes ports through which forces are moving, damage is done to the throughput capacity of the ports, the forces temporarily located therein, and the sealift assets that carry the forces.

All forces are represented at a fairly high level of aggregation, as illustrated in Table 1. Ground forces are entered by division for Soviet and other Warsaw Pact countries, and by brigade for NATO (though there is some flexibility to change these choices in the data base). Theater air forces are aggregated by type (such as F-15 or A-10) in a region. All of these forces carry an indication of the current alert, mobilization, and training levels, as well as other information on the likely effectiveness of the forces, strategic lift requirements for the forces, and so forth.

Once in a theater, two different kinds of geographic representations are used. In theaters with good transportation systems (such as Central Europe), the terrain is divided into army corps sectors following likely avenues of advance for invading forces. These sectors are subdivided into zones, providing a roughly gridded structure. Each zone carries information about terrain, throughput and crossput capacities, and other significant geographic features. In theaters with poor transportation systems (such as Iran), we represent the geography as a network, assuming no cross-country movement capability between elements of the network (see, for example, Levine, forthcoming). The network allows an attacker to move forward, change direction, and cut off defenders. The elements of the network become the corps sectors.

Table 1

SAMPLE GROUND AND AIR FORCES

Current Location	Divisions		Owner	Strength PCT	EDs	Ready Level	Assigned Theater
US-NE	1.00	US_armd	US	100%	1.0	60%	CEur
	1.00	US_inf	US	100%	.8	54%	CEur
	1.00	US_inf	US	100%	.7	50%	CEur
	0.33	US_mech	US	100%	0.3	65%	CEur

Current Location	Owner	Assigned Theater	Type-A/C	Class	PAA	#A/C
US-SE	US	Intercon	KC-135	tanker	33	33
	US	Intercon	ANG-Tnk	tanker	8	8
	US	CEur	F-15	fighter	168	168
	US		F-15	fighter	18	18
	US	CEur	F-16	multi	180	180
	US	NEur	F-4	multi	30	30

Within a theater, ground forces can be placed in a corps sector, held back in the theater reserve, or move from one location to another. Forces in a corps (or Soviet Army) sector are divided into first and second echelons, based on standard Soviet practices, with the first echelon forces further divided into engaged forces, forces covering the flanks, and a first echelon reserve. When forces capture opposing territory, they must also allocate some forces to occupation.

Without going into details, let us at least indicate some of the areas that require explicit modeling. For ground forces, we cover various aspects of combat strength, preparation of the forces for combat, deployment and strategic lift, force employment in combat (largely the TCL rules), adjudicating combat, and combat support. For air forces, we cover similar factors, and also the mission planning and sortie generation process. Theater nuclear forces are included as part of an overall targeting and damage assessment approach that cuts across conventional and nuclear forces.

Because the Force Agent must support a war gaming system, we have attempted to take into account the Red/Blue asymmetries in force planning and operations. For example, we designate each theater with both a Blue oriented term (e.g., Central Europe or CEur), and a Red oriented term (e.g., the Western TVD or WTVD). For mission planning of tactical aircraft, we allow the Red team to employ a system similar to that used by the Soviets, referring to aircraft classes and missions in generic Soviet as opposed to NATO terms.

We have attempted to make the system extremely flexible by allowing most significant parameters to be varied interactively. Many of these parameters are accessible to the Red or Blue Agents as TCL controls; other parameters reflect analytic uncertainties and thus can be varied only by a supervising analyst. We allow for changes to parameters as fundamental as the basic movement and attrition assumptions.

STRATEGIC FORCE OPERATIONS

With strategic forces, we attempt to capture all major aspects of force operation. As shown in Fig. 3 for the strategic bomber force, these include force preparation; launch and/or execution; the command, control, communications, intelligence, and warning systems; defense penetration; targeting and damage assessment; and force recovery and reconstitution. The following three examples will illustrate our modeling approach.

Consider first the problem of representing mobile surface-to-air missiles (SAMs). Interestingly enough, most "detailed" bomber penetration models ignore this issue (while treating other issues with great precision), because to handle it they would have to represent terrain and the road network, and indicate how SAMs would be dispersed over given terrain. Within our model--which is unabashedly less detailed--we simply attempt to capture the *effects* of mobile SAMs, by both increasing the penetrator encounter rate and reducing the probability of SAM suppression from attacks against prewar SAM sites. There are other secondary effects of mobile SAMs that we may also eventually choose to cover.
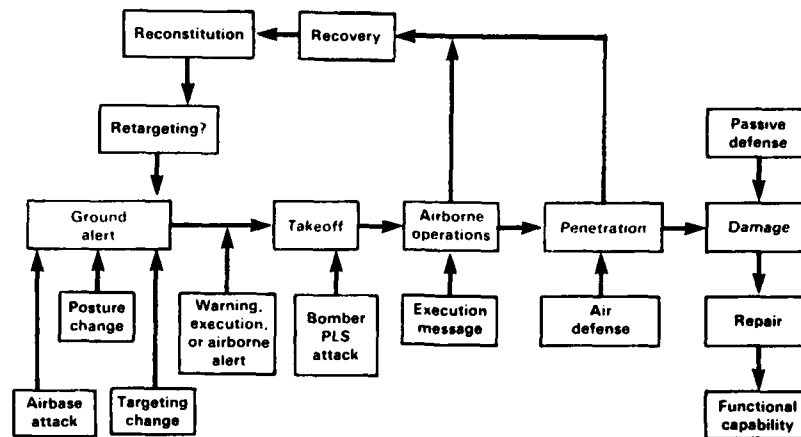
Fig. 3 -- Strategic Bomber Force Operations

In the targeting area, we have developed a robust system that cuts across all types of targeting problems, as suggested above. For strategic forces, we handle standard intercontinental targeting structures but also allow for significant variants such as limited options or force reloads. We also allow for a variety of alternatives with either theater or strategic forces in the theater.

In the damage assessment area, we attempt to follow both basic nuclear effects and the timing of the effects (such as in bomber prelaunch survival), where appropriate. We are also careful to distinguish targets and forces; for example, a nuclear attack against ground force bases that have been evacuated may destroy a number of buildings and some logistics support but will have little effect on the ground forces themselves. We distinguish between assets that are destroyed and those that are damaged but repairable, and handle both the repair and sustainability process (crudely, but significantly). Another major variation variation in our approach is to focus specifically on force *capabilities*. In doing so, we worry about the damage suffered by a force, its basic support assets, and the command/control structure required to bring the force to bear effectively. Each of these

components may be more or less susceptible to damage (e.g., an electric power network may be either robust or fragile, depending upon the percentage of targets that must be destroyed before the network ceases to function). Moreover, damage to any of these components may affect the performance of the force over varying time periods.

FORCE AGENT OUTPUTS

The Force Agent has a rather broad range of output formats available for displaying either the current situation or the situation as it has changed over time. Many of the displays available are tabular and represent the current situation. A graphics interface is also available that produces maps and drawings of the current situation. Finally, a history file (produced by the Force Agent) allows the user to plot time trends of approximately 5000 measures of effectiveness cutting across the various modeling areas. The graphics capability is by no means a mere adjunct or "nice to have"--it has become a fundamental part of our approach to both gaming and analysis. For example, human teams use graphic depictions of projected results before deciding on alternative courses of action.

IV. THE ROLE OF AUTOMATION

After two years of intensive development and some experience with applications, we are beginning to understand the role of automated war gaming in strategic analysis. Again, we caution that these conclusions are tentative, and that we are gaining more experience all the time. However, we hope that they help provide some perspective on what we have learned so far.

SOME INITIAL COMMENTS

Let us start with an observation about RSAC philosophy. Many models and war games already include some degree of automation, often implicitly within their structure. For example, most nuclear attack models have a weapon allocator that performs the targeting function, and this allocator is clearly a form of decision automation. As in this example, most current forms of automation tend to be some type of optimization procedure for a simplified definition of the problem, with only minimal constraints (e.g., maximizing the damage done per weapon expended). By contrast, most RSAC work adopts something closer to an expert-system approach in which we attempt to capture the decision processes military planners actually use, rather than those they could "optimally" employ if their problem were simpler.

Next, let us comment on how reviewers react to automation. Typically, before analysts and war gamers are willing to use an automated system, they focus on three issues (and almost always in the same order). First, how good are the underlying analytic models? If the models are not very good, then no matter how much effort goes into automation, the resulting product is not worthwhile. If the models are good, then how good is the automation process itself? How has the automation process been accomplished (e.g., by seeking expert opinion?), and how much effort has been expended? Does the automation capture what is likely to occur in a true military operation, or does it reflect an operations research perspective without military realism? Finally, if both the models and the basic automation process look good, to what

extent can the automation be varied to capture alternative perceptions of reality? Is the automation environment friendly and transparent enough, and are there tools available to support making changes? It has been gratifying to see that reviewers care about the features that have been so difficult to achieve.

APPLYING AUTOMATION

The value of automation varies with the intended application. Consider two examples of possible applications for the RSAC: war games carried out for training and war games carried out for analytic purposes.

In a training mode, we presume that a human team is playing against a fully automated opponent; for example, a group of U.S. military officers are playing as Blue against an automated Red. Since gaming for military training purposes is a common requirement in the Department of Defense, it is clear that a gaming system operating in this mode would significantly reduce the manpower required to support such games by removing the need for human Red teams. Moreover, the decisions made by the automated Red team would be consistent and documented, allowing for better postgame analysis. However, there are several tradeoffs. First, a significant amount of pregame activity would have to go into the preparation of the automated Red Agent, so that it could be responsive to a wide range of possible Blue actions. Note, however, that this may well be a one-time investment, with only marginal efforts required to enhance existing plans and characteristics before the second and subsequent plays of a game. Second, since many of the Blue team players would probably have only a casual acquaintance with the gaming system, the human interface would have to be truly interactive and user friendly, and the models and assumptions of the game would have to be fairly transparent. Finally, the Blue team would have to have a wide range of displays available to support its requirements for information.

We should also note that, in our experience with other systems there are two significant sources of potential frustration in training applications. First, the human team often fails to understand what is happening because appropriate displays and warning notices are not included in the game, and therefore not much training really goes on.

Second, if the human team has difficulty believing the actions taken by its opponent (because the automation process has not been good enough), it may refuse to continue or turn to "playing the game" rather than accomplishing useful training.

In an analytic mode, both Major Agents may be automated. The human becomes an observer rather than a player in this mode, with the game proceeding as fast as the computer is able to run until some form of conflict termination occurs. We expect that complicated wars of perhaps 30 days of game time will run in about an hour of computer time using this mode--much less than one might expect from purely human gaming. The actual computing time depends on computer performance (e.g., VAX-780), scenario complexity, number of theaters, and other factors. However, once again, there are tradeoffs. Ar in the above example, this mode requires a large amount of time to prepare the automated Agents. Perhaps more important, although the computer may take only an hour to run through the game, humans may require many hours or days to figure out what has happened and why; in this effort, a key factor will be the availability of appropriate displays and diagnostic messages to allow the analyst to follow what has transpired. One interesting frustration that may occur is that the analyst is unable to control the scenario that develops except by changing the personality of the Major Agents and the war plans they have available. That is, one cannot always ask for a specific scenario with, for example, a particular number of days of mobilization and preparation before war: the character of the automated Agents will determine the duration of the preparation phase. The point here is that scenario is an *output* of a fully automated RSAC war game, not an input. In practice, of course, we are trying to have our cake and eat it by parameterizing the key decision rules so that we can reproduce standard scenarios if we want to. Also, a team can overrule the automated models.

CONCLUSIONS

Let us emphasize again that the purpose of our structure is not to take the human element out of gaming, but rather to provide a flexible framework in which various approaches are possible. Even in the automated mode, humans are completely responsible for preparing the war

plans and other aspects of the expert systems that become the Major Agents. If anything, humans must expend even more time after the games to analyze what has happened and why.

To date, we have found value in both human and automated war gaming within the overall RSAC framework. We have a significant amount of experience with the human war gaming system, and some experience with the fully automated approach using a very early, partially complete version of the system. We are about to begin experimenting with the current fully automated prototype system to enhance our knowledge in this area.

V. REFERENCES

Bennett, Bruce W., "Strategic Forces Modeling," unpublished, 1982.

Brown, T. A., and E. W. Paxson, *A Retrospective Look at Some Strategy and Force Evaluation Games,* The Rand Corporation, R-1619-PR, September 1975.

Davis, Paul K., and Cindy Williams, *Improving the Military Content of Strategy Analysis Using Automated War Games: A Technical Approach and an Agenda for Research,* The Rand Corporation, N-1894-DNA, June 1982.

Davis, Paul K., and James A. Winnefeld, *The Rand Strategy Assessment Center: An Overview and Interim Conclusions about Utility and Development Options,* The Rand Corporation, R-2945-DNA, March 1983.

Davis, Paul K., *Rand's Experience in Applying Artificial Intelligence Techniques to Strategic-Level Military-Political War Gaming,* The Rand Corporation, P-6977, April 1984.

Graubard, Morlie H., and Carl H. Builder, *Rand's Strategic Assessment Center: An Overview of the Concept,* The Rand Corporation, N-1583-DNA, September 1980.

Levine, Robert, *Flying in the Face of Uncertainty: Alternative Plans and Postures for Interdiction in Southwest Asia,* The Rand Corporation, P-7050-RGI, forthcoming.

THE ROLE OF AUTOMATED WAR GAMING IN STRATEGIC ANALYSIS   Bruce W. Bennett and Paul K. Davis

RAND/P-7053

END

FILMED

8-85

DTIC